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ON THE COVER:

Our cover photograph, taken at AFCRL's Sagamore Hill Radio Observatory, shows the oscilloscope trace of Pulsar CP-0950. Two pulse signals, at an interval of 0.253 second, are clearly seen. Radio physicist William Ring is at the oscilloscope.

The newly discovered pulsars, or rapidly pulsating celestial radio sources, emit electromagnetic radiation over a wide frequency range measured between 40 and 2,700 MHz. This radiation is in the form of pulses of approximately 50-millisecond duration at a repetition rate on the order of 1 second.

AFCRL has observed all the pulsars discovered to date and is analyzing their characteristics. AFCRL astronomers have used these precisely timed pulsar signals in studies of ionospheric scintillations.

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Wide-Band (Visual-Spectrum) Photoelectric Photometry of the Pageos Balloon Satellite During its First 15 Months in Orbit

RICHARD C. VANDERBURGH, General Physics Research Laboratory, ARL

Photoelectric sensing of sunlight scattered from orbiting objects has proved to be a simple, efficient, and inexpensive means of determining many of the physical and dynamical properties of spacecraft. (1) The author has collected and analyzed such data from over 150 space objects over a period of 3 years. Of the many orbiting objects studied, balloon-type spacecraft have shown optical signatures of particular interest. One of these, the so-called PAGEOS (for Passive Geodetic Satellite) balloon, is considered here.

Observing equipment at ARL (Figure 1) consists of a 4-axis-mounted, 24-inch Cassegrain telescope equipped with a highly sensitive photomultiplier tube in a logarithmic feedback circuit for wide dynamic range, a local-time reference, and suitable recorders. The 4-axis arrangement allows precise manual guiding. An experienced observer can maintain a target in a 2-arc-minute field aperture at apparent angular velocities up to 2 degrees per second.

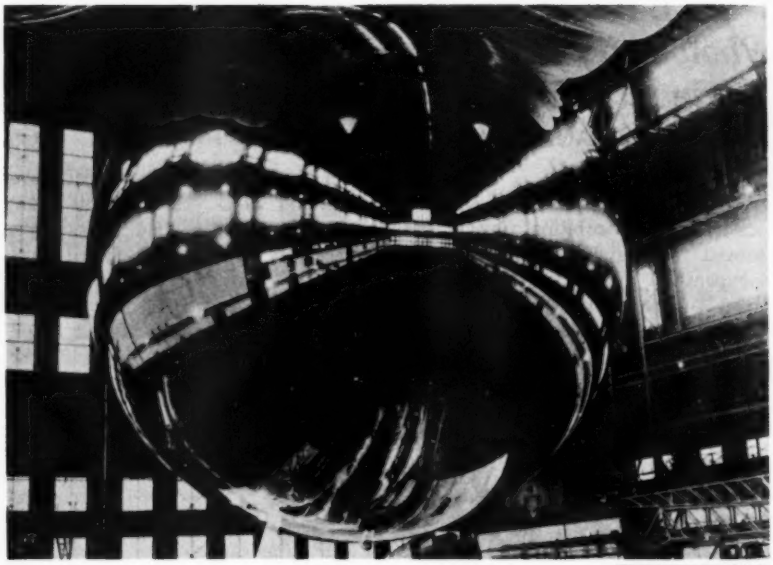
On 24 June 1966, the payload which was to become PAGEOS was launched from the Western Test Range

Figure 1. Mr. Vanderburgh operating ARL's 24-inch, 4-axis mounted Cassegrain telescope.

in support of the National Geodetic Satellite Program. (2) Upon injection into an approximately circular orbit 4,200 km above the earth's surface, the balloon was inflated to a nominal 100-foot diameter by the sublimation of benzoic acid and anthraquinone powders. Less than 8 hours later, as PAGEOS was beginning its third circuit of the earth, the ARL photoelectric tracking system became the first to measure the brightness and variations of brightness with time of the sunlight reflected from this shiny, orbiting "ball bearing" with its 15-meter diameter. (Figure 2 shows an inflated PAGEOS balloon on the ground.) During the next 15 months, as local visibility allowed, there were frequent collections of photoelectric data, with observations amounting to some 10 hours on 25 transits.

Had PAGEOS been a perfect sphere of uniform reflectivity, the scattered sunlight would have been constant and therefore of little interest, except perhaps as a calibration target. However, from our photoelectric measurements of earlier balloon satellites, Echo I, Echo II, and Explorers IX, XIX, XXIV, we knew that one could expect surface anomalies large enough to cause significant brightness fluctuations. (3) Careful interpretation of these fluctuations could then be used to measure the development or decay of rotation of the spacecraft about its center of mass. Longer-term changes in absolute brightness and color can be used to study changes in surface reflectivity, changes in the diffuse/specular ratio for the total received flux, and in the over-all shape.

The initial photoelectric data showed definite although small periodic anomalies in the spacecraft surface which produced an increase in brightness of 25 percent of a few seconds, too little to be detected by eye or in photographs. Significant changes in these anomalies occcurred over the 15 months of monitoring, sometimes with dramatic swiftness. (Figure 3 is a composite of oscillograms representing log-observed brightness as a function of time for selected transits.) Between the records of 27 June and 11 July 1966, PAGEOS went



Courtesy of NASA

Figure 2. PAGEOS ground inflation test.

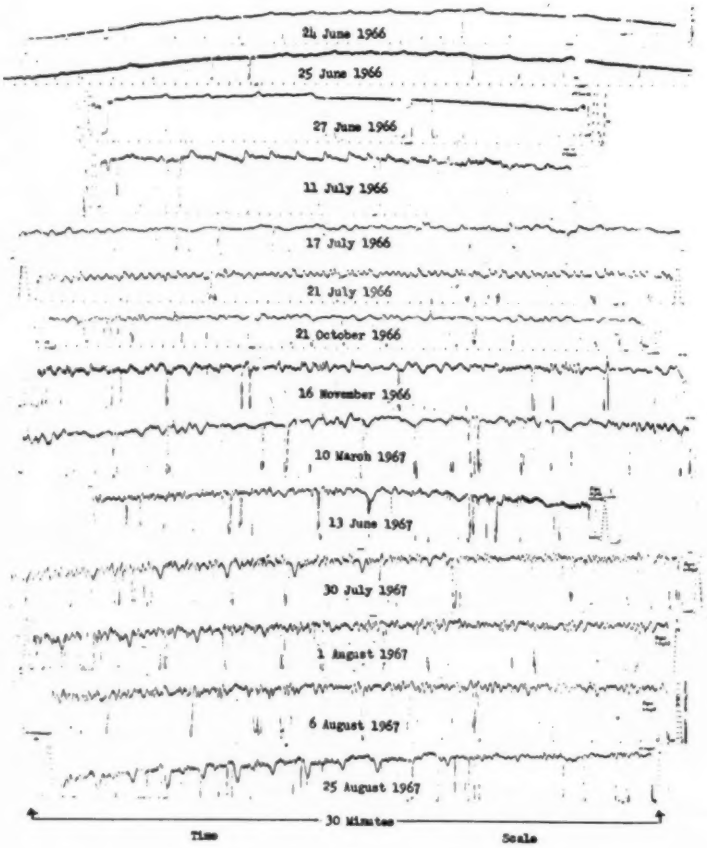


Figure 3. Composite of PAGEOS light curves.

from a condition of continuous sun illumination to one where part of each orbit was in darkness (the sun was eclipsed by the earth). The surface irregularities evident in the 11 July record suggest that, as the satellite made a transition from full sun illumination to darkness, the resulting temperature drop caused wrinkling of the glued mylar skin through production of thermal stress, or perhaps through the resolidification of residual inflation material and its accretion on the skin. (4) The apparently periodic anomalies in these early months in orbit are not clearly cyclic, although they definitely suggest rotation.

Later data, especially those collected in August and September 1967, do show cyclic patterns in the brightness fluctuations, making it possible to infer the rotational period of the balloon about its center of mass. (Figure 4 is a plot of the apparent rotational period as a function of time.) While the early rotational measurements seem to fit well, their noncyclic nature carries the possibility that they represent submultiples of the true rotational period. However, measurements made from the winter of 1966 to the fall of 1967 show a definite spin-up over 245 days, amounting to an increase in rotational kinetic energy of about 4 joules. The average torque required to produce this energy change was found to be of an order of magnitude (9.30×10^{-6} newton-meters) such that it could be accounted for by such weak forces as solar-radiation pressure or the earth's magnetic field. The only suggestion to date on a mechanism for rotational acceleration is one which evokes continuous thermal distortion of the shape due to the temperature distribution about an already rotating thin shell in sunlight. (5)

During one turn of the balloon about its center of mass, a virtual image of the sun is observed to trace a spiral-like path along the surface only some four to eight centimeters wide. This size of the sun's virtual image is determined by the local surface curvature of the reflecting surface and from the conclusion that surface reflectivity remains almost entirely specular, (3) an assumption justified by the absence of phase angle effects (in contrast with the moon, which is almost entirely diffuse).

At any instant in time, the observed brightness of the reflected solar image is a function only of the surface reflectivity, the local radius of curvature of the surface in the solar highlight and, of course, the slant range to the object. If one assumes constant reflectivity (highly probable due to the observed lack of significant surface degradation), (4) and accounts for the slant range through knowledge of the orbit, then observed brightness fluctuations are interpretable in terms of variations of the radius of curvature or as skin wrinkling.

Since the radii of curvature of a closed surface are interrelated, the brightness fluctuations associated with curvature changes must follow patterns allowed by a closed surface, i.e., it must be possible to join observed radii of curvature into continuous curves traced on the closed surface. Thus, the short-term fluctuations which show no patterns associated with the satellite's rotational position are most probably due to skin wrinkling, the predominant observed condition. However, beginning in July 1967, a repeating pattern characterized by two well-defined brightness drops per rotation cycle was often observed, a pattern which would occur if the trace on the spacecraft repeats itself almost exactly on some rotational latitude. The most pronounced such pattern occurred on 15 September 1967. (Figure 5 shows the observed data, and an interpretation leading to a PAGEOS cross section resembling an egg as the most probable [most spheroidal] figure consistent with observations.)

In summary, it has been demonstrated that photoelectric photometry is a useful method for determining some of the physical properties of highly specular artifical earth satellites. In particular, it has been shown that, for the PAGEOS balloon satellite at slant ranges often exceeding 5,000 km, the following characteristics can be measured: 1) surface microstructure (relative contributions of specular and diffuse reflectivity); 2) macrostructure (skin wrinkling); 3) over-all structure (size and shape); and 4) dynamical rotation about the center of mass. As accumulated over a 15-month interval, these measurements constitute a physical history virtually from the birth of the spacecraft, which should be of interest to investigators of satellite dynamics in the near-earth environment, as well as to engineers concerned directly with the fabrication and deployment of balloon spacecraft.

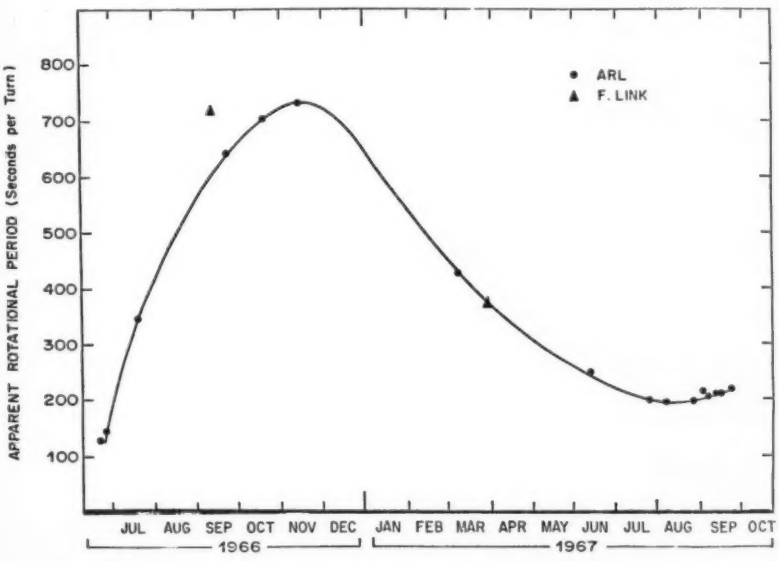


Figure 4. The apparent spin of PAGEOS.

Photometric observations of the PAGEOS spacecraft are being continued along with those of all other balloon-deployed vehicles.

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Mr. Richard C. Vanderburgh, a research space scientist (satellite tracking) with the General Physics Research Laboratory, was first employed at ARL under an Ohio State Research Foundation contract in October 1964. He subsequently joined the ARL scientific staff under a U.S. Civil Service appointment in May 1966.

In 1950, Mr. Vanderburgh received his B.A. degree in Economics from the University of Hawaii. In January 1951 he joined the Air Force, receiving basic training at Lackland AFB, primary aviation cadet training at Goodfellow AFB, and advanced pilot training at Reese AFB. As a pilot-rated second lieutenant, he flew 100 combat missions from Kimpo airfield in Korea, and returned to Shaw AFB, completing his tour of active service as an instructor-pilot.

In December 1955, Mr. Vanderburgh joined Pan American World Airways as a pilot-navigator and, from a San Francisco base, flew scheduled routes throughout the Pacific area and the Orient. He entered the satellite-tracking field as a Smithsonian Baker-Nunn observer at the Hawaii station atop Mt, Haleakala, in 1959. From 1961 to 1964, he served as the Smithsonian's Director of project MOONWATCH, co-ordinating the efforts of several hundred amateur satellite trackers located throughout the world.

Mr. Vanderburgh's current work includes the collection of optical data with ARL's 24-inch, 4-axis mounted telescope at Sulphur Grove, Ohio, the refinement of prediction and reduction techniques, the initiation of technical reports, and liaison with individuals and groups engaged in co-operative efforts. He has a number of publications to his credit.

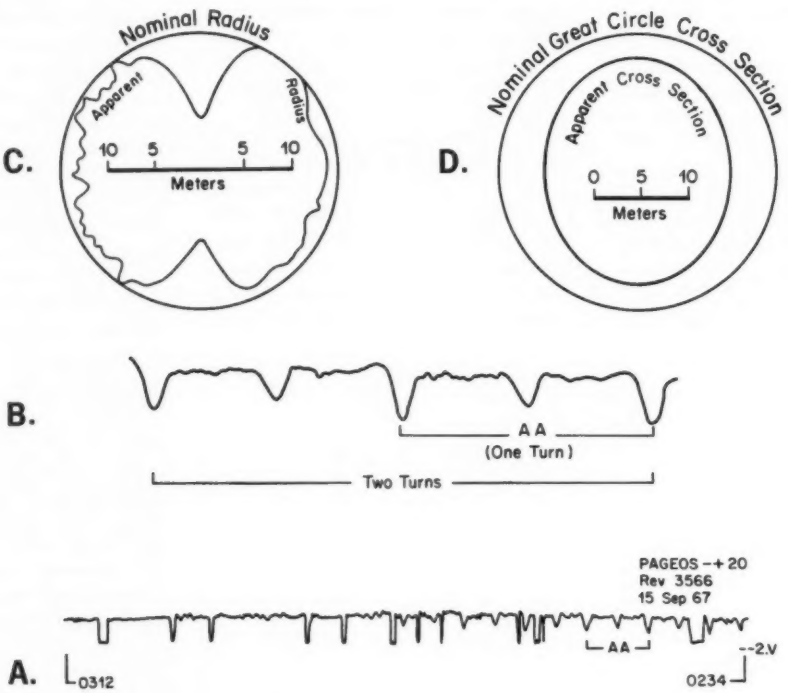

Figure 5. Reduction of light curve of 15 September 1967.
A. Entire light curve of PAGEOS transit during the 3,566th orbit.
B. Expanded section of light curve during two revolutions of PAGEOS about its center of mass.
C. Apparent radii of curvature from brightness data at AA.
D. Apparent cross section of PAGEOS from measured radii of curvature.

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ARL

fluid mechanics of a hypersonic slipper bearing

The increase in speed of rocket-boosted sleds on test tracks, such as the facility at the Air Force Missile Development Center, Holloman AFB, to several thousand feet per second subjects the rail-guided supporting slippers to very severe aerodynamic heating and friction. Due to several catastrophic failures of slippers at speeds in excess of 6,000 fps, the Hypersonic Research Laboratory, ARL, in cooperation with the Test Track Directorate of AFMDC, has made a theoretical investigation of the flow occurring between the slipper and rail at hypersonic speeds. (1)

A cross section of the slipper and rail in a typical configuration is schematically shown in Figure 1. The

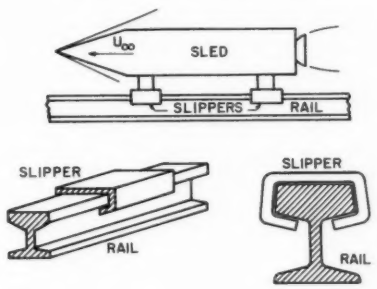

Figure 1. Typical rocket-sled configuration and slipper details.

slipper—approximately 6-12 inches long—is constructed of stainless steel and is wrapped around a 4-inch crane rail allowing a 1/8-inch gap between the slipper and rail. The inner surface of the slipper is subjected to high heating rates by either fluid friction from air flow in the gap or by sliding friction in the event of metal-to-metal contact between slipper and rail.

Although the slipper bearing is subjected to many accelerations and perturbations as it travels down the test track, as a first step toward understanding the problem, the aerodynamics of the slipper is studied for a steady-state configuration and speed. The gap height and slipper thickness are small compared with the rail width and depth, so that the flow field about the slipper may be considered two-dimensional.

Analysis of the flow in the gap between slipper and rail leads to a model divided into the following elements: (1) compression due to the slipper bow shock; (2) stagnation region on the leading edge of the slipper; (3) boundary-layer flow; (4) mergence of the slipper and rail boundary layers toward (5) a Couette flow asymptote.

With respect to the bow shock structure, the relative dimensions of slipper thickness and gap height are such that neither a regular nor a Mach reflection is possible. Therefore, it is assumed that the flow traverses a normal shock. This assumption is within the same degree of accuracy as that of the approximations used—that is, uniform flow in the inviscid region, slipper-wall temperature atmospheric (that the rail temperature is atmospheric is exact), and a perfect gas. The heat rates on the leading edge of the slipper are calculated using the classical results of Fay and Riddell (2) for a perfect gas and laminar flow.

With respect to shear flows in the gap, in view of the high densities associated with atmospheric conditions and based on practical slipper dimensions, Reynolds numbers are high—of the order of 10^7. Therefore, flows are expected to be turbulent.

The flow entering the gap is retarded by the slipper (shock-fixed coordinate system) and entrained by the rail so that the respective boundary-layer displacement thicknesses are of opposite sign. In fact, calculations show that the effective inviscid channel is slightly divergent for cold walls, implying that sonic conditions exist at the minimum effective section, which is essentially the gap entrance. (Note that the flow must expand supersonically to low pressure at the base of the slipper.) In this case, the mass flow is determined completely by the slipper geometry and, for a given gap height, is a function of free-stream Mach number only.

The dimensions of the slipper configuration are such that the boundary layers will merge some distance from the leading edge to form a full shear flow which, at some distance downstream, will tend toward turbulent Couette flow. A schematic drawing of the flow regions is presented in Figure 2.

The boundary-layer results on the

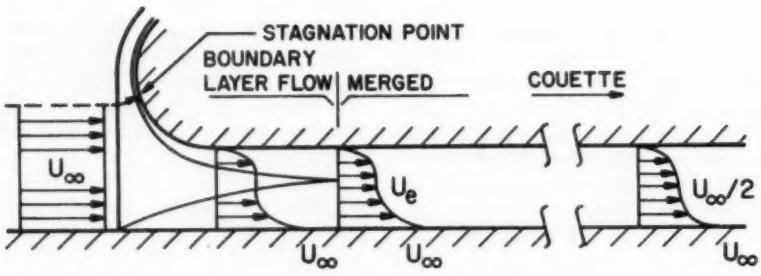

Figure 2. Velocity profiles in gap.

slipper in the region of separate boundary layers are described using a standard turbulent compressible boundary-layer theory (3) with external sonic flow, while the boundary layer on the rail is identical to a compressible turbulent shock-tube boundary layer (4) with external flow at a low supersonic speed. Both boundary-layer theories are modified to include the compressible coefficients of Spalding and Chi (5) modified by Komar. (6) Experimental evidence presented by Nerem and Hopkins (7) supports the validity of this theory for the case of high wall cooling. The lower bounds of heat-transfer rate and gap pressure are found from compressible turbulent plane Couette flow theory. (8)

Couette flow is not expected to be reached in most configurations; however, the asymptotic lower limits of heat rate and pressure provided by the Couette theory enable one to estimate the merged region values. Typical heating-rate and pressure distributions on the slipper are shown in Figures 3 and 4.

Calculations of the mechanical heating due to sliding friction for typical slipper loads and configurations show that the aerodynamic heating problem is at least as great as the mechanical heating problem.

Two important conclusions can be drawn from the theoretical analysis:

(1) The aerodynamic heating rates encountered along the slipper are of the same order as the stagnation-point heat rates, and are severe—more severe than those encountered on reentry vehicles.

(2) The pressure distribution along the slipper causes the configurations to be statically unstable. That is, if the slipper is perturbed—in pitch, roll, or yaw—from some equilibrium position, the net aerodynamic force on the slipper will change so as to make the slipper continue to move in the perturbed direction.

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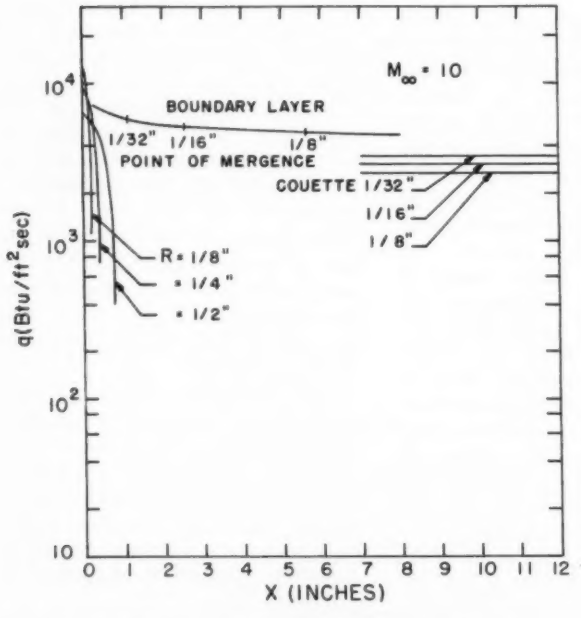

Figure 3. Heat-transfer rates along slipper: M_∞ = 10.

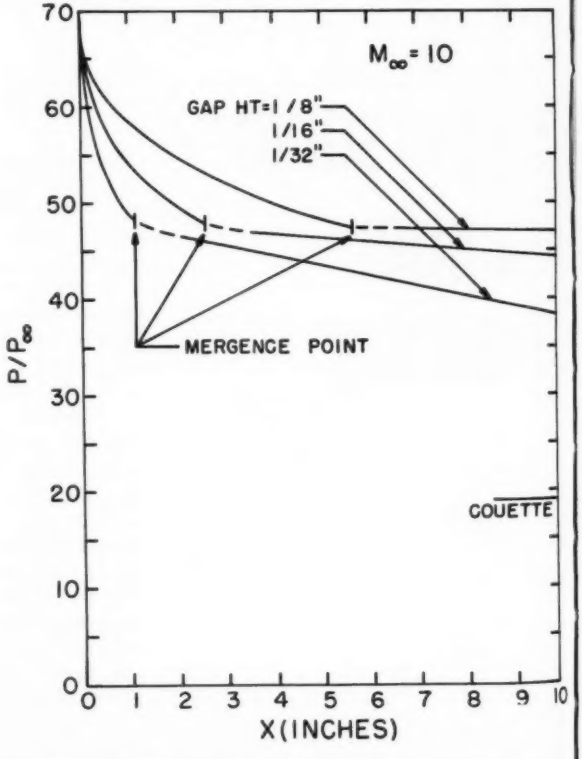

Figure 4. Pressure distribution along slipper: M_∞ = 10.

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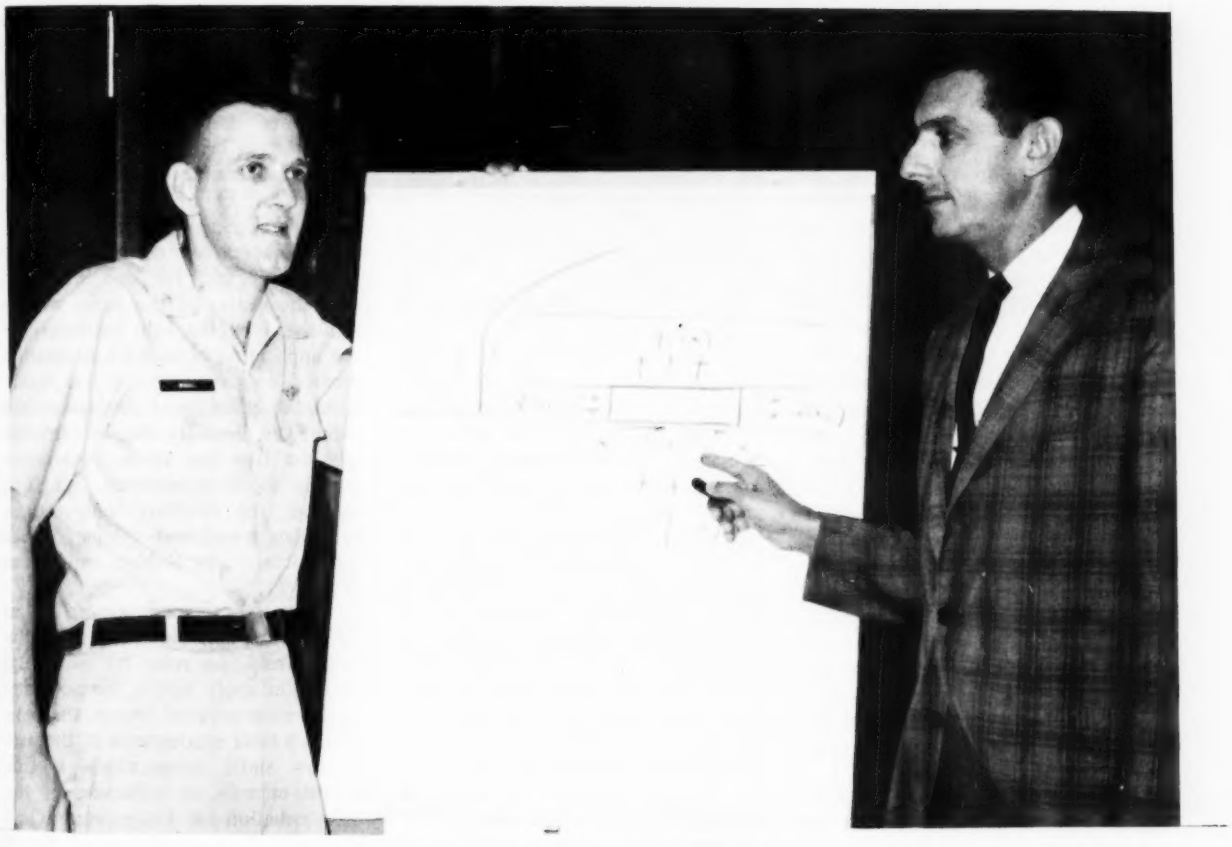

Major Ronald A. Briggs (left) began his military career by enlisting in the Air Force in 1953. In 1954 he entered the Aviation Cadet Program, receiving in 1955 his commission as a Second Lieutenant and his Navigator's Wings at Ellington AFB, Texas. After completing the Advanced Strategic Bombardment Course at Mather AFB, California, he was assigned to the Strategic Air Command, serving with it in various unit deployments to Guam, Japan, Canada, Alaska, Hawaii, Johnson Island, England, and Spain.

In 1964, Major Briggs received his Bachelor's Degree in Aeronautical Engineering from AFIT's Residence Engineering School. Upon graduation, he was presented the Mervin E. Gross Award as the outstanding undergraduate student, and was selected to be an exchange graduate student at the College of Aeronautics, Cranfield, England. For these latter studies, he received the Diploma of the College of Aeronautics, and was awarded an M.S. Degree in Aerospace Engineering from AFIT.

Major Briggs is presently assigned to the Hypersonic Research Laboratory, ARL, as an Aerospace Research Engineer.

Dr. Robert H. Korkegi, Director of the Hypersonic Research Laboratory, joined ARL in May 1964 after almost seven years in Brussels, Belgium, as Technical Director of the von Karman Institute for Fluid Dynamics. This Institute is a graduate-level academic and research organization for advanced work, primarily in experimental fluid mechanics, established for the benefit of the NATO countries.

During the summer of 1956, as a consultant to the Advisory Group for Aeronautical Research and Development (AGARD-NATO), Dr. Korkegi lectured on research in hypersonic aerodynamics at the Sorbonne, the University of Poitiers, and the C.N.R.S. (Paris), and advised on the planning of hypersonic facilities in France and Belgium.

Dr. Korgegi received his Ph.D. degree in Aeronautics and Mathematics at the California Institute of Technology in 1954. He had previously completed his undergraduate studies in mechanical engineering at Lehigh University, where he received the B.S. degree in 1949. During World War II, Dr. Korkegi enlisted in the U.S. Army and served in the Combat Engineers in England, France, and Germany from 1944 to 1946.

advances in the electron-beam diagnostic technique regarding low temperatures

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Laboratory simulation of flow fields with supersonic and hypersonic wind tunnels is an established technique; there is still a lag, however, in the development of adequate flow-calibration methods. The calibration items of interest for a test facility can be grouped into three main categories: (1) those associated with the gasdynamic state; (2) those describing the chemical nature of the effluent; and (3) the variables specifying the local thermodynamic state. Spectroscopic techniques for measuring the radiation emitted from atoms and allowing the determination of vibrational and rotational temperature as well as the number density of the radiation specimen have been known for many years. The application of such techniques to the area of experimental rarefied gasdynamics came into play when other methods failed to give satisfactory results. Spectroscopic techniques are particularly attractive since they can be employed without causing any disturbance in the gas during the diagnostic process.

This is a discussion of nonradiating flows as they exist in expanded supersonic or hypersonic gas flows of low density. The excitation of the gas particles is accomplished by an electron beam. This beam of high-energy electrons passes through the gas, and the electrons collide with gas particles and impart a certain portion of their kinetic energy to the internal energy of the heavy gas particle. The heavy gas particle, excited through the collision, will emit radiation during a spontaneous transition to its ground electronic state. Instead of radiating, the excited particle could also collide with another particle during the lifetime of the excited state, giving up the excess energy, which is called collision quenching. The latter is responsible for the upper limit of gas density to which this technique can be applied.

Another limitation has troubled the researchers for a long time, namely, the lower limit of temperature which could be measured with reasonable accuracy. Studies conducted by Robben and Talbot (1) and Marrone (2) with free jets have indicated that, at temperatures below 300°K, the measured rotational temperatures were appreciably higher than the true values. Correction factors were developed but could only be applied to data obtained in a specific test arrangement since the cause of the erroneous results was not known. Various calibration experiments (3) were performed in an attempt to understand the mechanism responsible for the errors occurring at lower temperatures. However, in all electron-beam calibration experiments made until now, the conditions under which the data were obtained may have contributed to uncertainties in the final conclusions. Data obtained with a free jet arrangement suffer from the possible existence of rotational nonequilibrium and flow conditions at the test point and are difficult to define. Gas flows of low velocities may influence the values of obtained data by beam heating and the accumulation of metastable particles in the region of observation.

In order to eliminate all factors which could lead to uncertainties in the determination of causes leading to the observed errors, Dr. S. L. Petrie (4) at the Ohio State University Research Foundation initiated an investigation of the characteristics prevailing in the electron-beam technique. For his experimental studies he utilized a perfect gas wind tunnel where the local flow conditions were free of rotational nonequilibrium and could be determined very accurately. It was conjectured that the intensity distribution in the electron beam might be responsible for the errors occurring in measuring lower temperatures. A high-quality optical system was used to avoid scattering of the electron beam. The rotational temperature profile through the beam was measured. It was found that, in the immediate region of the primary electrons, there was little variation in temperature but, as the traverse continued outside the immediate cross section of the beam, the indicated temperatures began to increase. This observed phenomenon, which may be called a halo around the primary beam, is characterized by higher rotational temperatures than those within the main beam. The line intensities near the center of the beam will be influenced by the halo radiation. By the application of an Abel integration method to the measured line intensities, the influence of the halo on the main-beam intensity can be removed and the true line intensity variation through the beam obtained. Using this method, the resulting temperatures were determined and compared with those obtained by Robben and Talbot (Figure 1).

For static temperatures as low as 20°K, the data indicate that the optical selection rules for rotational excitation apply within the accuracy of the measurements. Hence, the temperature error encountered in the past at low static temperatures is due almost entirely to influences of the halo radiation on the measured line intensities. Those results are significant since they clearly allow conclusions regarding the applicability of the excitation-emission process originally proposed by Muntz (5) and used by many investigators.

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Mr. Emil J. Walk is Chief of the Hypersonic Facility Branch, Fluid Dynamics Facilities Research Laboratory, ARL. He has been with the Air Force since 1946 and with ARL since 1952, when he joined it as general engineer for wind-tunnel research and development.

After serving a 4-year apprenticeship in toolmaking and tool design in his native Nuremberg, Germany, Mr. Walk studied mechanical engineering at the Bavarian State Higher Technical Institute and was graduated in 1928 among the top 10 in his class.

In his present position, which he has held since February 1965, he is responsible for the operation of the ARL hypersonic wind tunnels, the planning and design of new facilities or components, and the development of electronics connected with the instrumentation and controls for these facilities.

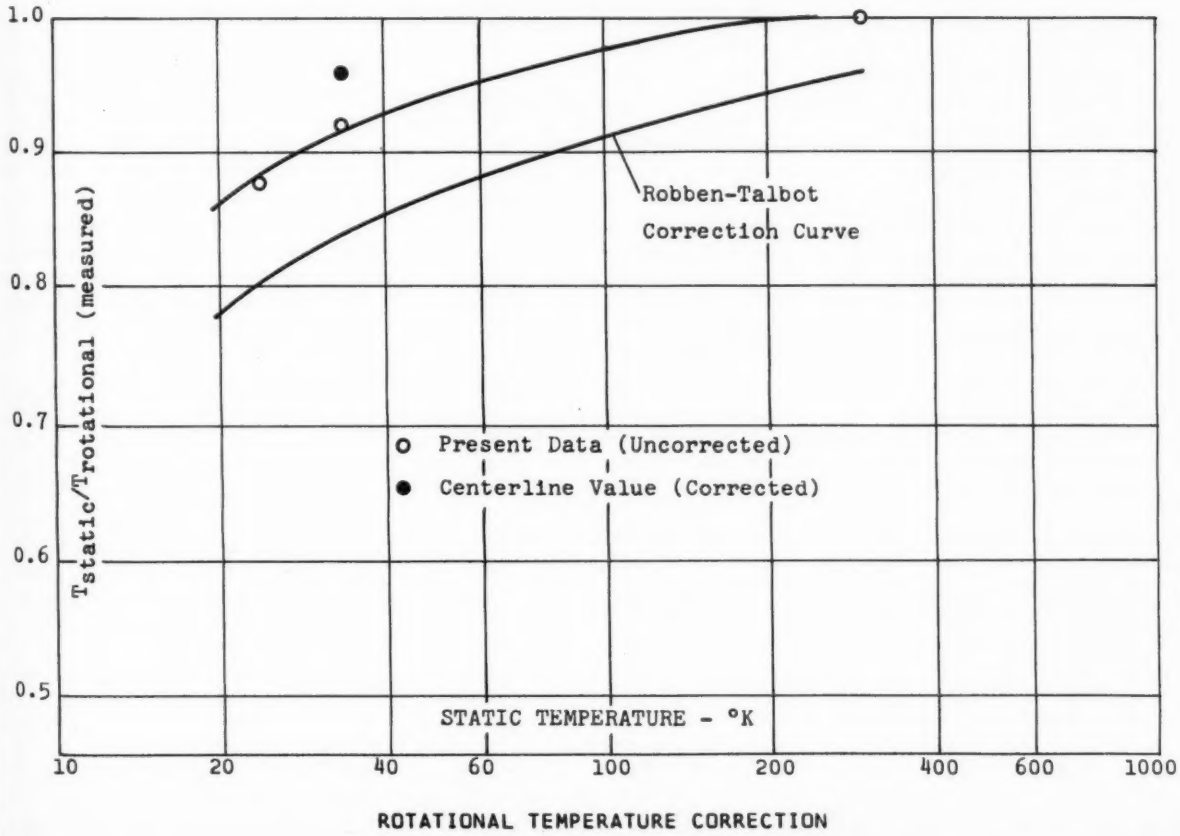

Figure 1. Results of Petrie method compared with those obtained by Robben and Talbot.

WEATHER MODIFICATION TREATED IN SYMPOSIUM PROCEEDINGS

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The Berkeley Symposia in Mathematical Statistics and Probability are held every five years, to "stimulate research through lectures by carefully selected speakers and through prolonged personal contacts of scholars brought together from distant centers." Under the aegis of the Statistical Laboratory of the University of California at Berkeley, the Fifth Berkeley Symposium was held during the periods 21 June through 18 July 1965, and 27 December 1965 through 7 January 1966. It was cosponsored by the University and a number of Government agencies, including the Mathematics Division of AFOSR.

The recently published *Proceedings** appears in five volumes titled, respectively, *The Theory of Statistics, The Theory of Probability, Physical Sciences, Biology and Problems of Health,* and *Weather Modification.* The first volume on *The Theory of Statistics* includes sections on "Information Theory" and on "Nonparametric Procedures." The volume on *Physical Sciences* includes sections on "Control Processes and Reliability." The volume on *Weather Modification* represents an innovation, as was the decision to devote a special section of the Symposium to this subject. This latter volume and section were designed to stimulate "novel statistical research, theoretical as well as empirical, ... beneficial both to statistics and to applied meteorology." However, the decision to examine the results of recent cloud-seeding experiments was made in the light of several interesting facts.

Over the last 20 to 25 years,a number of cloud-seeding experiments have been conducted in various countries. As a result, to the extent that cloud-seeding experiments might be considered to have influenced rainfall, it has appeared that the influence could be positive or negative–in other words, that rainfall might be increased or decreased by seeding.

Another consideration of some importance is the inherent difficulty of conducting such large-scale tests, in terms of the time, effort, and expense involved, and the difficulty of deciding which physical parameters should be measured, how they should be measured, and the statistical methodology to which they should be subjected. In view of this, the volume on *Weather Modification* includes a substantial collection of data from cloud-seeding experiments conducted in five countries (the United States, Australia, France, Israel, and Switzerland). Evidently, this collection of experimental results can provide a basis for the attempted verification of new hypotheses which are formulated.

One of the papers included in this volume, that of Professors J. Neyman and Elizabeth L. Scott of the University of California at Berkeley, defines the *general statistical problem* of weather modification as the formulation of a methodology for using such "precious experimental data" in the most efficient manner, so as not to waste the information provided by such observations.

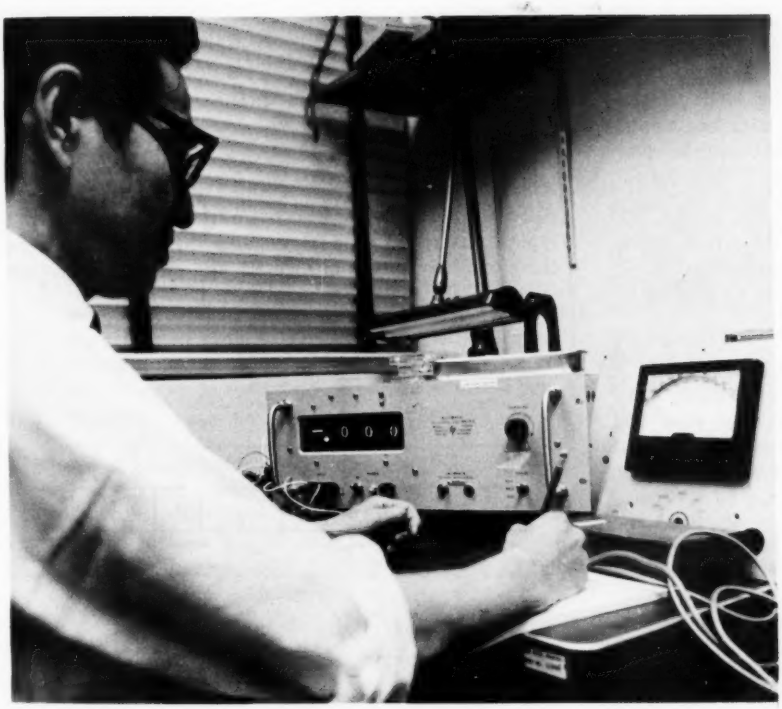
The same authors define the *basic premise of the meterological problem* as the existence of at least two sets of synoptic conditions, A and B, under which the seeding of clouds has opposite effects: under conditions A, it increases precipitation, and under conditions B, it decreases precipitation. In a series of storms or "rainy incidents" over a given locality, these conditions A and B are mixed in varying proportions. It is this varying frequency of conditions A and B which is responsible for the results of a number of cloud-seeding experiments: too many days with conditions B were included in a series of tests, with the net conclusion that seeding has either a negative or null effect upon the rainfall.

The authors also state that conditions A and B have not been identified, and that there exist only vague hypotheses regarding them. However (and this is the authors' *second premise),* these two sets of conditions are identifiable in terms of the usual meteorological parameters. Consequently, the *foremost outstanding substantive problem of rain modification by cloud seeding* is the identification or definition, in terms of meteorological parameters, of conditions A and B.

Other papers in this volume and their conclusions are as interesting, and readable, as the above. Various statistical tests were used in past experiments, and other statistical tests are proposed for future use. Many of the papers are arresting in their frankness, and a number of them illustrate the physical complexity of conducting any large-scale experiments, e.g., as they relate to the airborne dispersion of any chemical including a defoliation agent.

In conclusion, it seems appropriate to refer the interested reader to this and the other volumes of the *Proceedings* for further details. Substantial support for this section of the Symposium was provided by the Atmospheric Sciences Section of the National Science Foundation. However, the importance of the Mathematics Division's support of basic research in statistics and, indeed, of its partial support of this Symposium are exceptionally well demonstrated by this volume on *Weather Modification.* It was admittedly for this reason, and also because of the over-all Air Force interest in the solution of problems of weather modification, that this article was written for the *OAR Research Review.*

**Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability,* Volumes I-V, edited by L. M. Le Cam and J. Neyman, Berkeley and Los Angeles: University of California Press, 1967.



COSMIC RAYS AT SUPERSONIC-TRANSPORT ALTITUDES

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When planning for the supersonic transport (SST) first got under way, some people feared that cosmic rays penetrating the rarefied atmosphere at the 60,000-to-70,000-foot altitude of the SST would provide a radiation hazard to passengers and crews. These fears were subsequently allayed, but with a residual uncertainty. Recently, Mr. Katsura Fukui of AFCRL has reported on the results of 3 balloon flights to supersonic-flight levels to obtain quantitative data on the energies and fluxes of heavy cosmic-ray nuclei. The results of these tests, although not fully definitive, pretty much lay the issue to rest. There appears to be negligible cause for concern.

The danger, it was thought, would arise primarily from heavy cosmic-ray nuclei—atoms completely stripped of electrons and having masses that may be as great as that of iron and charges as high as 26. When such a nucleus enters the atmosphere, a radiation dosage of several thousand rads is deposited along its entire trajectory. The encounter between the nucleus and a body cell can destroy the cell. Certain body cells are particularly vulnerable. Most sensitive are cells in the lens of the eye, reproductive cells, and hair follicles, the destruction of which results in the graying of the hair.

In the AFCRL experiments, 3 balloons carrying photographic emulsion plates were sent aloft to SST altitudes and higher. The 3 experimental packages each consisted of a stack of about 100 emulsion plates, each plate measuring about 3 inches square. These stacks, in effect, simulated atmospheric density, representing a compressed vertical cross section of the atmosphere. The penetration of a heavy cosmic nucleus to a certain depth in the emulsion stack corresponded to the penetration of the nucleus to a certain depth in the atmosphere. The 3 balloon flights were made to altitudes where the total weight of the atmosphere above was, respectively, 3, 38, and 58 grams per square centimeter, corresponding to altitudes of 130,000, 70,000 and 60,000 feet. (At sea level the weight of the atmosphere overhead is about 980 g/cm^2.)

Although a heavy cosmic-ray nucleus causes ionization all along its path, its greatest destruction occurs near the end of its trajectory when it interacts with atmospheric atoms or molecules (or, correspondingly in the AFCRL experiment, with emulsion atoms or molecules) causing a spray of secondary electrons. Only heavy nuclei with an atomic number greater than boron were analyzed in the 3 emulsion packages. The 3 balloon flights averaged about 15 hours each. A total of 391 tracks were analyzed in the 3 emulsion blocks.

The analysis, after correction for several factors such as the latitude and the angle at which the cosmic-ray nucleus entered the emulsion block, produced some rather smooth plots of atmospheric penetration as a function of atmospheric depth and particle energy. These plots show that, above about 80,000 feet, the absorption of the cosmic-ray energy is very rapid. Below that depth, the rate of attenuation decreases somewhat and becomes approximately exponential. The number of heavy nuclei encountered at the SST flight level of 60,000 to 70,000 feet was calculated to be only a few percent of the number encountered at the top of the atmosphere.

This strong atmospheric shielding, coupled with the additional shielding of the aircraft-fuselage metal, serves to protect the passengers and crew almost completely from the ionizing radiation of heavy cosmic-ray nuclei.

Mr. Katsura Fukui, shown measuring the charge of a heavy primary cosmic-ray nucleus, is a physicist in the Cosmic Radiation Branch, Space Physics Laboratory, AFCRL. He is currently investigating cosmic-radiation phenomena through the use of nuclear photometric emulsions. During the winter of 1958-1959 he observed and analyzed the auroral spectrum at College, Alaska, in order to estimate the velocity of incoming protons.

Mr. Fukui received his B.S. in Physics from Nagoya University, Japan, in 1945, and his M.A. in Physics from Boston University in 1958. He did further graduate work at Tufts University from 1959 to 1963. He has several publications to his credit.

automata in motion

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An automaton, to the mathematician, is a model of a system that he constructs in terms of input, output, and internal states. Automata theory is that branch of mathematics concerned with the logical manipulations that can be effected on the inputs and internal states to produce or predict particular outputs.

The more popular concept of an automaton is of a self-moving device (after the Greek root, *automatos*, or self-acting). The building of machines, particularly those that imitate the movements and sounds of men and animals, has held the fascination of inventors throughout the ages. Is there more than coincidence or wishful thinking in today's use of the word, "automaton," by mathematicians, information scientists, and computer scientists?

As a first approximation, at least, both natural and mechanical systems can be described as automata in the mathematical sense. They can be considered as divisible into a finite number of internal states that are acted on by a finite number of inputs, the internal state (y_{n+1}) of a system at any given time depending only on the immediately prior state (y_n) and the input (x_n) to it. Automata theory provides for deterministic systems in which y_n and x_n uniquely determine y_{n+1} and the output, and for probabilistic systems in which y_n and x_n only determine the probability that y_{n+1} and a particular output will occur. For y_n and x_n to suffice as determinants of y_{n+1} or the probability, however, y_n must include a record of such past history of the system as may be required. This past history may be called "memory." Thus, knowing the y_n of a digital computer, which is a finite automaton, means knowing the contents of all of the registers of the machine that are relevant to the output of the nth state. Automata theory is used in designing circuits that are specified by the input-output transformations they must accomplish. By analogy, other systems for which models are being developed include neural networks, molecule and cell replication, and human psychological behavior. Applications to living systems usually pose more difficulties because of their complexity and the fact that many of their states are not known.

One of the areas in which automata theory is being tested is that of limb movement. Authoritative data permit comparison here between theory and living systems. (1) This article discusses research on finite-state aspects of locomotion conducted by the Department of Electrical Engineering at the University of Southern California (USC) under Grant AFOSR 67-1018. The approach of this research illustrates the nature of the inquiry necessary to exploit automata theory for automaton development.

USC's research is based on Rajko Tomović's observation that an animal's leg can be idealized to a two-state device, viz., on-the-ground and in-the-air, respectively. (2) For a finite-state machine, these can be the 1-state and the 0-state, respectively. A shift register, constructed from standard two-state electronic flip-flop modules, is a machine realization of the sequence of states associated with a typical quadruped walk. By varying the frequency of the clock oscillator shown in Figure 1, the period of a gait can

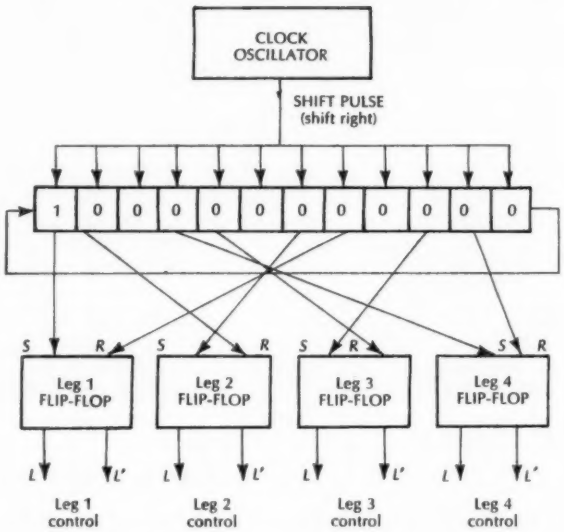

Figure 1. Shift-register realization of a sequence generator for a quadruped walk.

be changed without altering the sequence of the leg states. The sequence and relative duration of successive states can be modified through interconnections between the flip-flops.

To incorporate the control systems embodied in the natural quadruped leg, the device requires more than two states. Dr. Robert B. McGhee's USC model has knee and hip joints, each driven by separate dc motors; either motor can be connected to a positive, negative, or zero voltage source, corresponding to forward rotation, rearward rotation, and locked states, respectively. Thus, each joint is a three-state device. (Four states appear necessary for an approximation to the natural biped gait.) The desired leg-output-state sequence for a particular gait depends on a control algorithm for the internal states. (3)

In his definitions of terms used in formulating a finite-state theory of locomotion, Dr. McGhee has associated the terminology of physiology and anatomy with that of the mathematical theory of sequential machines. These definitions include the following:

1. A *leg* is a sequential machine m with two output states, 1 and 0. The two states are referred to as the support phase (m = 0) and the transfer phase (m = 1, leg above the support surface).

2. A *locomotion automaton* M is an indexed set of legs. $M = \{m_1, m_2, \ldots, m_k\}$.

3. A *gait* for a locomotion automaton composed of k legs is a periodic sequence of binary k-tuples representing the successive states of the legs of the automaton. In any complete cycle of a gait, the state of every leg must change exactly once, from 0 to 1 and from 1 to 0.

4. A *gait matrix* G is a k-column matrix whose successive rows are binary k-tuples corresponding to the successive states of a particular gait of a k-legged locomotion automaton, and whose total number of rows is equal to the length of one cycle of the gait sequence.

5. A *gait realization* is a specific locomotion matrix G, together with a particular duration vector t.

6. A *gait formula* g for a particular mode of locomotion of a k-legged automaton is a point in a unit (2k-1) cube defined by

$$g = (\beta_1, \beta_2, \ldots, \beta_k, \phi_2, \phi_3, \ldots, \phi_k)'$$

where β is the duty factor or relative amount of time that a leg is in the 0 state and ϕ is the relative phase of the leg defined as the ratio of the transition delay time to the cycle time for a given duration vector.

With these definitions, several elementary theorems have been proved. They are supplemented by others that enable exploration of various types of gaits. Gaits realizable by regular symmetric gait formulas have been most extensively studied. Several of the definitions, for example, have consequence for the design of automatic controllers that co-ordinate movement. (4)

Two control hypotheses were investigated. One postulates a single center of control that transmits commands to each joint in a predetermined sequence appropriate to the desired mode of locomotion. The second envisages interaction of autonomous control networks without a central source of commands. In the terminology of control theory, these alternatives correspond to open-loop and closed-loop control. In sequential machine theory, these modes of operation are called synchronous and asynchronous, respectively. Dr. McGhee has shown that both synchronous and asynchronous controllers can accomplish limb co-ordination. For his synchronous automata, Dr. McGhee assumed dynamic stability in the gaits that he considered. This assumption will probably not apply for biped-type movement. Asynchronous control algorithms are more complicated due to the distributed control function. An asynchronous control algorithm was realized that achieves leg co-ordination for the quadruped crawl gait.

Results of this research demonstrate that finite-state automata are suitable tools for studying the properties of living systems. The abstractions further an understanding of the kinds of specifications that are needed to build complex command-and-control systems. Dr. McGhee's research could have direct application to prosthetics and to the design of vehicles for irregular terrain. The algorithms, however, more generally describe the behavior of dynamic systems and their information requirements for particular modes of operation.

Although Robert A. Heinlein's power suit (5) is still within the realm of science fiction, it is becoming increasingly possible to see the relationship between the advances of such fundamental concepts as homomorphisms and congruence relations and work on abstract algebras, on which automata theory is based, and robots that can walk on the moon, mechanical hands that can manipulate delicate apparatus, and mechanical brains that can augment those of man or function independently in remote environments.

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(One of the principal sources today for data on the movements and gaits of animals are the records made by Eadweard Muybridge between 1872 and 1885. A vignette on Muybridge may provide insight as to how research originates and becomes channeled to applications. Muybridge was directing photographic surveys for the U.S. Government on the Pacific Coast when a controversy arose in San Francisco as to whether or not all four feet of the horse, even while trotting, were ever simultaneously off the ground. Muybridge's photographs proved that they were. He became interested in photographing animal movement to settle more general and conflicting theories and opinions. This led him to devise a system for obtaining a succession of automatic exposures at prespecifiable time intervals that he described in a paper published in the *Proceedings of the Royal Institute of Great Britain* (Mar. 1882). He was able to enlist the aid of Mr. Leland Stanford, who permitted him to photograph horse movements on his stock farm on the present site of Stanford University. Unable to continue this work except intermittently, he was successful in obtaining full-time sponsorship in 1884-1885 from the University of Pennsylvania through the intercession of the then-Provost, Dr. William Pepper who, as Muybridge wrote, has an "enlightened" view on the role of the university as a contributor to human knowledge. During this period, Muybridge invented the zo-opraxiscope for synthetically demonstrating movements from photographs. In 1888, he consulted with Thomas Edison on the practicability of using the zo-opraxiscope in conjunction with the phonograph, which was then not found possible. However, in 1898 Muybridge wrote that "there can, however, be but little doubt that in the perhaps not far distant future, instruments will be constructed that will not only reproduce visible actions simultaneously with audible words, but an entire opera, with the gestures, facial expressions, and songs of the performers ...")

(2) Dr. Tomović is now a Professor on the Faculty of Electrical Engineering, University of Belgrade, and scientific adviser at the Institute "Mihailo Pupin," Belgrade. In 1960-61, he was a visiting lecturer at USC, and returned in 1964 as a National Science Foundation fellow. His interests have significantly stimulated early USC research.

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AEROSPACE INSTRUMENTATION LABORATORY, AFCRL

cold temperatures over North America

A small 200-mile-wide pocket in the Yukon close to the Alaskan border and midway between the Pacific and Arctic Oceans is probably the coldest spot in North America. At least it is the coldest by one criterion—it has had the longest duration of extreme cold during a 10-year study period. Temperatures within this pocket remained continuously below −50° F for more than 150 hours during one especially bitter winter, and below −60° F for 50 continuous hours.

This is one of many facts on cold-temperature extremes over the North American continent that can be drawn from a recent study, "Duration of Cold Temperature Over North America" (AFCRL 68-0232), by Paul I. Tattelman of AFCRL. For his study, Tattelman used temperature data from 108 stations across the United States and Canada covering the 10-year period which ended in 1960.

When we consider the duration of relatively mild temperatures of −30° F, our attention shifts from the Yukon to an area in the arctic archipelago west of Northern Greenland between the 75th and 80th parallels. There, during one year of the 10-year period, temperatures remained below −30° F for 16 straight days. Not even the Yukon remains so cold for so long.

Looking at still milder temperatures—those of about −10° F that persist for 2 to 10 hours—we see that the lines of equal-temperature gradient tend to follow the Pacific coastline from the Aleutians southward across British Columbia into eastern Washington State and then southeasterly to the high elevations of New Mexico. Thus, if we discount differences in elevation, the extremes of cold from the Alaskan and Canadian coasts inland to about 50 miles are no more severe than those found in the southern Rockies.

In the United States, temperatures of 0° F or colder endure longest over northwestern Minnesota, northern North Dakota, and northeastern Montana. People in these areas can expect, with a 50 percent probability, to find temperatures at or below 0° F continuously for more than 75 hours during any single winter season, and at or below −30° F continuously for more than 10 hours during 1 out of 10 winters. The coldest single area in the United States is along the North Dakota-Canadian border.

The lowest temperature ever recorded in North America was −81° F at Snag, Yukon Territory. Although this record low temperature did not occur during the decade of Tattelman's study, the lowest temperature recorded (−78° F) during the 10-year period was also at Snag.

Mr. Paul I. Tattelman received his B.S. in Meteorology from the Pennsylvania State University in June 1967, and came to the Design Climatology Branch, Aerospace Instrumentation Laboratory, AFCRL, the following July. Currently engaged in statistical studies of meteorological parameters, he is taking graduate courses in statistics this winter. He is a professional member of the American Meteorological Society.

Mr. Paul I. Tattelman compares temperature-probability estimates for different places in North America.

THE FUTURE OF SCIENTIFIC DATA

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In July 1968 a $286,500 study, funded by the Advanced Research Projects Agency for the COSATI TAsk Group on National Systems, and conducted under the monitorship of the Directorate of Information Sciences, AFOSR, was completed by Dewitt O'Kelly Myatt and Bill Farris of Science Communication, Inc., Washington, D.C. This *Study of Scientific and Technical Data Activities in the United States,* the tangible evidence of this effort, is in three large volumes (AD 670606, AD 670607, and AD 670608) totalling 1,188 pages, as follows:

Volume I, 266 pages, presents a plan for the study and implementation of national scientific-and-technical-data-systems concepts.

Volume II, (Parts A and B), 433 pages, presents screnarios of data activities in 10 selected fields of science and technology: aerospace science and technology; electronics and electrical engineering; materials science and engineering; chemistry and chemical engineering; agriculture and food technology; biomedical sciences; pharmacology; social and behavioral sciences; environmental and geosciences; and, oceanography—covering the characteristics of data, data flows, formal data efforts, and representative data-related problems or issues identifiable with the field.

Volume III, (Part C), 489 pages, consists of a preliminary census of 226 formal data efforts which are representative of those currently operating in the United States, including data service centers, data-document depositories, data program development and co-ordination, and data handling and service operations.

Like the small boy who, having lost a dime in the backyard, was looking for it in the living room because the light was better there, we have focussed our attention during the post-Sputnik years on documents which, for all their faults, at least come in neat packages with front covers, back covers, and convenient handles such as personal and corporate authors.

However, the comparative glamour of documents has tended to obscure their relative unimportance, vis-à-vis technical data. The Institute for Basic Standards of the National Bureau of Standards reports that approximately 20 *billion,* measurements are made *each day* in the United States (1). Over $25 billion has been invested in instruments to make these measurements, and roughly $10 billion is expended each year on personnel to operate these instruments and related systems. The National Science Foundation estimates that the Federal Government obligated $412 million in FY 68 for the collection of general-purpose data. These are defined as: "Newly gathered statistics, observations, readings, specimens and other facts...from such activities as surveys, filed investigations, laboratory analyses, or compilations of operating records which can be applied to useful, general scientific purposes...This definition *excludes* data gathered from the R&D process or from scientific and technical information activities. Also excluded are data used only for internal operating or administrative purposes." The data in OAR's Management and Scientific Information System (MASIS) would thus be excluded.

And the Department of Defense estimates that it expends annually approximately $2 billion to acquire items of scientific and technical data. But who would attempt to estimate the current value of the DoD investment in 50 million engineering drawings, 225,000 technical manuals, and other items too numerous to mention, for these represent the vital reservoir of engineering knowledge upon which the continued effectiveness of our defense system depends.

Since I am more concerned with the future of information systems than with their present status (except as a constant user and their sometime pathologist), (2) and since I do my humble best to stay out of the national biogeopolitical arena, I have selected 0.5 percent of the report for discussion here—that section which attempts to project future events and trends which would have an impact on scientific and technical data-handling systems. The set which follows is not internally consistent, since it was compiled from the opinions of many people. It does not represent an official Air Force position—yet. But for what it is worth, if only as grounds for discussion, here it is:

1968-1973	Computerized evaluation of experimental data in the area of nuclear cross sections.
1968-1973	Implementation of extensive computer systems which process evaluated data files for more effective use of data in design and development.
1969-1974	Use of high-density, photochromic microimage devices for digital file storage, capable of storing 400 pages per square inch with an access rate of 200 to 500 microseconds.
1969-1975	Full implementation of the United Engineering Information and Display System.
1970	Use of laser-luminescent display devices capable of good resolution.

1970-1972	Use of mass storage devices capable of storing 10^{12} bits of data.
1970-1972	Implementation of a data system for metals and materials properties.
1970-1974	Use of handwriting document readers for input, capable of reading a full character set at a rate of 50 characters per second.
1970-1980	Establishment of Federal Government data banks serving assorted agencies in the three branches of the Federal Government.
1972-1976	Printing of essentially all publications by electronic composition or photocomposition.
1972-1977	Full implementation of a National Chemical Information System.
1973	Availability of computer storage on a public utility basis.
1973	Direct access to large data banks on a service-and-fee basis.
1973	Discovery of a way to build modular software which is subsettable and based on an individual's needs and machine size, but which has almost the performance of a custom code.
1973	Extensive use of computers in "on-line" data-acquisition systems and "interactive" modes of operation, where the user and the computer form a complementary unit.
1973	Implementation of a National Physics Data Center.
1973	Implementation of a working national data and document network in the field of medicine.
1973	Implementation of well-developed mechanisms and data banks in machine-readable form in several of the existing information services, such as *Chemical Abstracts.*
1975	On-line recall and remote-terminal display of the most frequently needed handbook data simultaneously with the presentation of the problem being attacked.
1975	Implementation of community-operated and community-owned computer centers, available to small industry, schools, public libraries, etc.
1975	Satellite communication of scientific data via television circuitry between established national systems in the free world.
1975	Use of small personal computers for personal files.
1975	Telecommunication of scientific papers or data prior to publication, with the option of inputting to a storage and retrieval system.
1975	Creation of an integrated index for environmental data, embracing the contents of data centers for weather data, oceanographic data, space and aeronomy data, seismological data, geodetic data, gravity data, geomagnetic data, etc.
1975	Expansion and vitalization of the National Referral Center, with more effective interconnections with other information services.
1975	Implementation of educational computer networks on a nation-wide scale.
1975	Replacement of institutionalized data centers with national data/information centers in areas where institutionalized centers duplicate, overlap, or fail to provide services.
1975	Utilization of flat displays with a resolution of 0.1 mm or better, in sizes of one square meter or better.
1975	Implementation of multiprocessing computers with a throughput equivalent to one nanosecond per operation (one billion operations per second per system).
1975	Designation of specific institutions in national data/information systems as agents responsible for providing services, at standard fees, to all qualified users in the economy.
1978	Implementation of an Electrical and Electronic Engineering Data Center.
1980	Use of three-dimensional, colored display devices.
1980	Joint operation of EDUCOM, National Standard Reference Data System, National Chemical Information System and National Physical Information System.
1980	Use of mass storage devices capable of storing 10^{18} bits of data.
1983	Implementation of a National Social Sciences Data Center.
1983	Domestic access to data in libraries and information centers.

1983 Replacement of conventional hard-cover books with newer information media, such as microforms, e.g., hyperultrasupermicrofiche.

1983 Widespread use of voice-recognition devices, for example, for spoken input into computers.

And, for those who haven't read the book:

1984 Replacement of libraries in the conventional sense with computerized, filmed stores of information, with film readers and computer consoles for reading rooms, browsing, and so forth.

See you then!

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neutralizing the oxygen ion: electron transfer versus ion-molecule reaction

AERONOMY LABORATORY
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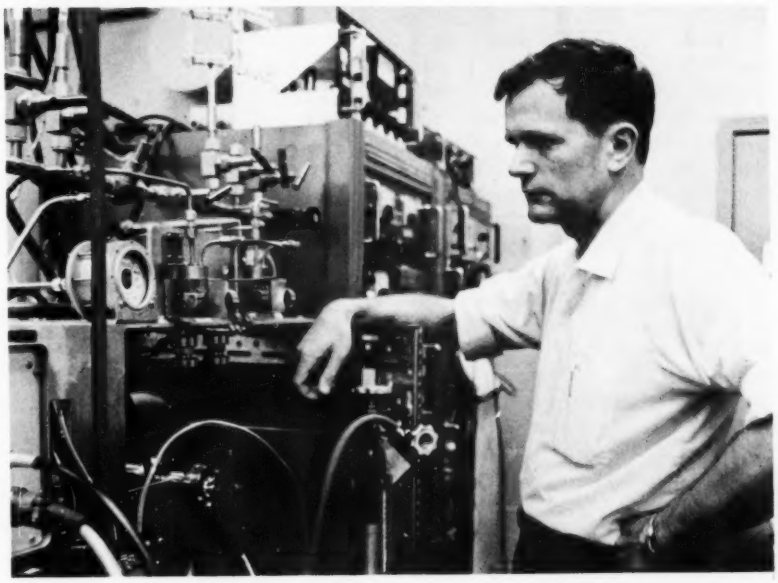
The oxygen ion, O^+, is one of the most common of the charged particles that make up the ionosphere. If we isolate just one such ion, we see that it doesn't remain in this particular state for very long. Its existence is marked by a kaleidoscopic pattern of transfigurations. It may collide with another atom or a molecule to become part of a molecular system, it may simply pick up a random free electron to become a neutral oxygen atom, or it may collide with a neutral molecule, pick up an electron and, from this encounter, emerge as a neutral atom.

Two reactions, both involving O^+, have been widely studied. These are $O^+ + O_2 \rightarrow O_2^+ + O$, and $O^+ + NO \rightarrow NO^+ + O$. Both reactions, in principle, may proceed through electron transfer (in which the original ion simply picks up an electron from the molecule), or by a more complex mechanism in which the neutral atom that emerges free from molecular constraint could be any one of the oxygen atoms in either of the reacting groups. Until recently, no one had any quantitative data on which of the two processes occurred more often.

Recently, Dr. John F. Paulson of AFCRL conducted a series of experiments using isotopically labeled oxygen ions. He has shown that in the cases of both the oxygen molecule and the nitric-oxide molecule, the reactions occur largely by simple electron transfer rather than by the more complex ion-molecule reaction.

In the simple electron-transfer process, Paulson found that the probability of reaction (the cross section) is independent of the O^+ kinetic energy in the range from 0.7 to 20 eV. When the more complex ion-molecule reaction takes place, it occurs at the low end of this energy range. At energies of about 1.0 eV, the probability that the neutral oxygen atom is produced by the ion-molecule mechanism is about 20 percent of the probability of its production by the electron-transfer process. Paulson also found that the ion-molecule reaction cross section decreases with increasing O^+ kinetic energy.



Dr. John F. Paulson, shown here using a double mass spectrometer, is a chemist in the Atmospheric Structure Branch, Aeronomy Laboratory, AFCRL. He has been with AFCRL since 1959. Currently, he is engaged in research on low-energy ion-neutral collision reactions of interest in the structure and dynamics of the upper atmosphere.

Dr. Paulson received his B.A. from Haverford College in 1951, and his Ph.D. from the University of Rochester in 1958. He has several publications to his credit.

earth's magnetic disturbance field: periodic patterns

METEOROLOGY AND SPACE PHYSICS LABORATORIES, AFCRL

The intensity of the earth's magnetic field varies from day to day. After certain regular variations are removed, the residual irregular variations constitute the geomagnetic "disturbance" field. These irregular variations have been recorded for almost a century with an index known to geophysicists as the International Magnetic Character Figure C_i. Intensity changes are most pronounced during active periods of the sun's 11-year sunspot cycle as huge bursts of corpuscular and electromagnetic energy from the sun disturb the earth's magnetic field. But even when the sun appears to be quiet, it may still modulate the magnetic field to induce cyclic fluctuations in the magnetic field.

To study this cyclic pattern, Drs. Ralph Shapiro and Frederick W. Ward, Jr., of AFCRL have subjected the daily magnetic-field values for a period of 72 years to a rigorous statistical analysis. From this they have derived high-resolution power spectra. The spectra show clearly the well-known 27.4-day variation of the disturbance field; but, in addition, Shapiro and Ward found a new secondary peak with a period of 29.4 days, and a third less-pronounced peak every 26 days.

While the 27.4-day peak stands out boldly, the real existence of the two smaller peaks was less certain. But, through several statistical processes and controls, Shapiro and Ward eliminated the possibility that the two subsidiary peaks were due to sampling fluctuations. Even when the daily data were separated into two 36-year periods, each independent sample confirmed the existence of the 3 peaks.

Once they were satisfied that the cyclic variations in magnetic-field intensity were real, Shapiro and Ward then offered possible reasons for their occurrence. The two men withstood the temptation to associate the peak that occurs at 29.4 days with the 29.53-day synodic period of the moon. This had, in fact, been suggested by others. Another suggestion, that the peaks are produced by an annual amplitude modulation of the 27-day peak, was also eliminated as a possible explanation.

After discounting any lunar influence or annual modulation, Shapiro and Ward offered 2 possible explanations for the quasiperiodic magnetic-field fluctuations. The first has to do with solar rotation, and the fact that the visible surface of the sun, the photosphere, rotates more rapidly at the equator (25-day period) than at the higher latitudes (31-day period near the poles). Thus, 3 quasipermanent active regions at varying solar latitudes, each with its distinctive rotation rate, could produce the 3 observed peaks. The second explanation postulates a residual magnetic field between the sun and the earth. This magnetic field could modulate the solar wind (speeding up or slowing down the transit time of the solar corpuscular radiation between the sun and the earth) which, in turn, could modulate the earth's magnetic field.

Neither explanation possesses much more rigor than simple speculation—which is to say that a fully satisfactory model has not yet been developed.

Dr. Ralph Shapiro, Chief of the Dynamics Branch, Meteorology Laboratory, AFCRL, has been working since 1952 on problems connected with the general circulation of the earth's atmosphere, including the problem of solar-terrestrial relationships. He has presented in a series of papers what is probably the first substantial evidence of a real response of the tropospheric circulation to variable solar-energy emission. He is now attempting to study such atmospheric responses theoretically, by the numerical integration of mathematical models of the atmosphere which incorporate solar variability as an external energy source. Dr. Shapiro has a B.S. in Education from Bridgewater Teachers College (1943), and an M.S. and D. Sc. from the Massachusetts Institute of Technology (1948 and 1950, respectively). He is a member of several professional societies.

Dr. Frederick W. Ward, Jr., is Chief of the Space Forecasting Branch, Space Physics Laboratory, AFCRL, where he has been working since 1963 on space environmental forecasting and the general circulation of the solar atmosphere. He received his B.S. in 1952, his M.S. in 1955, and his Ph.D. in 1957, all in Meteorology and all from the Massachusetts Institute of Technology. He has several publications to his credit.

Dr. Ralph Shapiro (seated) and Dr. Frederick W. Ward, Jr., are shown looking over power-spectra data.

This is an unusual photograph showing AFCRL's solar vacuum telescope at Sacramento Peak, N.M. silhouetted against a rare halo phenomenon. The halo results from the refraction by a thin layer of ice crystals at extremely high altitude.

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